How warm is the heart of Zagreb?

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Summary

The „Urban heat island effect/surface temperature field campaign“[1] inspired us to investigate more. Could we confirm that urban atmosphere is a thermal island in relation to the environment by surface temperature measurement? We asked whether the surface temperature values depend on: location; type of surface; measurement time; water surface proximity and snow cover. In periods 19. 2.- 2. 3. and 18. 4. - 22. 4. 2018 students measured the surface temperature of asphalt and grass surfaces at 7 stations twice a day between 6,00 - 6,15/ 21,00 - 21,15 using IR thermometers. During the first research period, surface temperatures were also measured at school stations at 12,00. When there was snow, the surface temperature and the underlay was measured both.

Results: Urban temperatures of grass and asphalt are higher than suburban, with lowest in the rural area, the “thermal island”[9] of Zagreb is confirmed with surface temperature values. The temperature of the substrate is mutually different, the influence of water proximity to the surface temperature of the grass substrate is confirmed, too. The measurement time hypothesis confirmed for grassy surfaces, asphalt shows the opposite. We verified that the snow is an insulator with lower temperature than the grass surface.

Key words: surface temperature, urban heat island

Introduction

IQ/Hypothesis

Guided by the fact that the air temperature in the city is on average higher than in the surrounding area, so the city atmosphere makes a thermal island related to the environment, we wondered if we could confirm this by measuring the surface temperature.

The structure of the city, artificial materials and ducted air flow are just some of the causes of the emergence of a heat island that gives a specialty to the city's microclimate. We were inspired by the GLOBE 'Urban heat island effect / surface temperature field campaign'.

Surface temperature is the temperature at which energy is emitted from the surface in the form of electromagnetic radiation. Radiation frequencies depend on the surface temperature.

The ground is a kind of "energy converter" that turns the shortwave radiation coming from the sun and passing through the atmosphere into the longwave radiation of the ground. The surface temperature can be determined by measuring the amount of radiation in the infrared part of the spectrum.

In the city, the elevated temperature is affected by the 'canyon effect'[8], the reduction of vegetation and the use of artificial air conditioning and heating.

We wondered if the surface temperature in the city center and in the suburbs differed. Due to previous research which confirmed that the air temperature in the city is higher than that in the suburbs and the surrounding area, we believe that the same trend will be with the surface temperature.

We also wondered if surface temperatures differed depending on the substrate. We expect that the asphalt will have a lower temperature than the grass surface or that the asphalt will cool faster than the grass surface during the night.

Further more we were interested in the differences in the values of southern and evening surface temperatures in urban, suburban and surrounding areas.

We expect that the surface temperature values measured in the early morning will be more similar among different locations than the temperatures measured in the evening. We expect these results because we believe that evening measurements will be affected by solar radiation during the day, that is, not all stations will be equally exposed to the sun.

In the morning measurements, we expect similar values between stations as the surfaces cooled down equally during the night.

We were also interested in whether the lake, as a climatic factor, has an influence on oscillations in surface temperature values. Due to the higher water content in the soil, the smallest oscillation, or the smallest amplitude of the surface temperature, is expected at a station near Lake Jarun.

We wondered if there would be a difference between the temperature of the snow and the temperature of the substrates. Our assumption is that the surface temperature will be higher because the snow will serve as an insulator and the snow temperature will be affected by the air temperature. Our assumption is that the surface temperature will be higher because the snow will serve as an insulator and the snow temperature will be affected by the air temperature.

Research methods and materials

Our research was conducted in two periods from 19.2. to 2.3. and from 18.4 to 22.4.2018. Seven students (Estera, Reina, Josip, Borna, Dorja, Matilda and Petra) participated. Students measured surface temperatures of asphalt and grass near the home for 12 days, according to the GLOBE protocol and they also used Surface Temperature Field Campaign Teacher's Participation Guide, Surface Temperature Protocol, Surface Temperature Data Sheet, Surface Temperature eTraining possibilities.

Students measured between 6.00 and 6.15 in the morning and between 21.00 and 21.15 in the evening. Selected asphalt and grassy areas were adjacent to the students' residence, and locations were chosen arbitrarily. It was important that the surfaces were not shaded during the day and that the distance between the asphalt and the grass was about five meters.

The measurement was performed by infrared thermometers, which we calibrated before .

In the period from 19.2. to 2.3.2018., but without a weekend, we measured the surface temperature at school stations. There we measured the temperature around noon.

On days when there was snow at the measurement stations, students measured the surface temperature of the snow and the surface temperature of the substrate.

While conducting our research we were constantly in contact with Dubravka Rasol, scientist in National Meteorological and Hydrological Service. She helped and supported us when collecting and analyzing data issues came up and pointed out how to interpret and present those data. As a result project was presented at Annual GLOBE Meeting in Croatia.

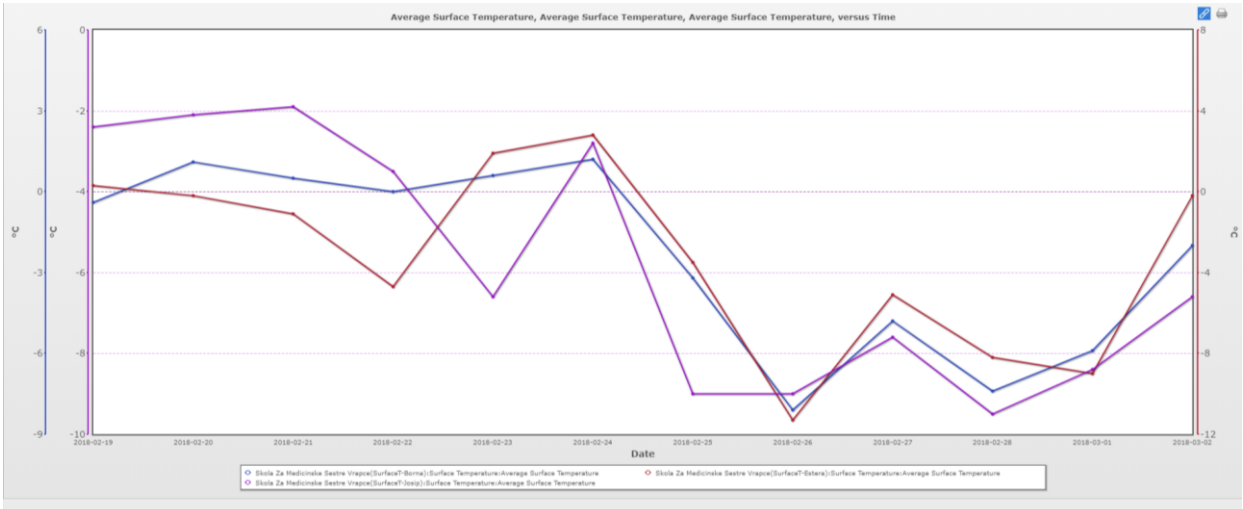
Picture 1. Geographical location of students measurements sites

We located the students on the map using the Google Earth program (Picture 1.)

After collecting data on the field we held meetings and compared them. Then we randomly decided who will insert data in GLOBE base, that way we all trained all the activities. We exchanged our observations between us and our mentors.

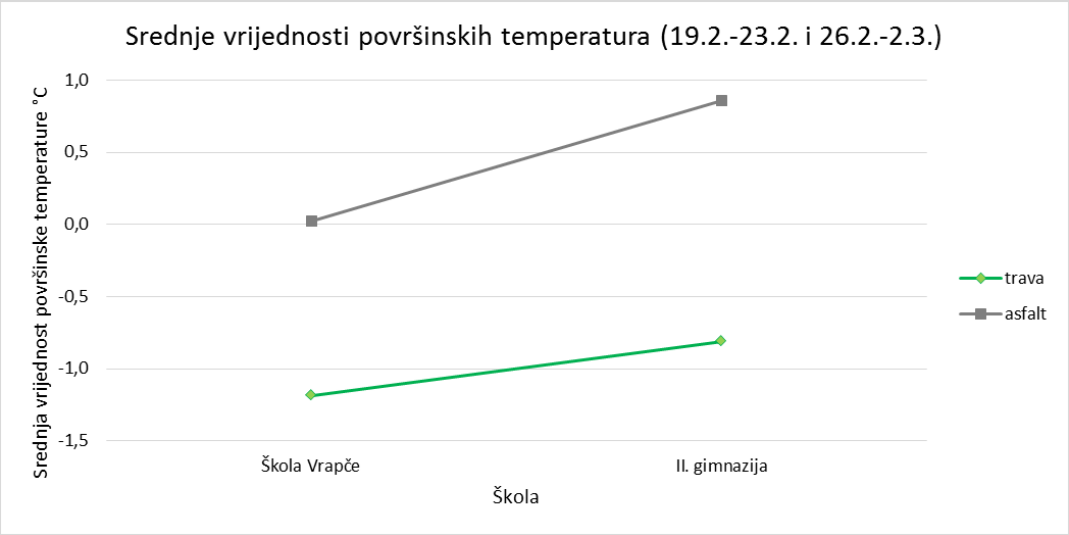
Results-Visualisation and data analysis

All the data were insert in GLOBE base and they are visible due to Visualisation app. After making individual graphs (Picture 2) we compared them and calculated average values in excel.



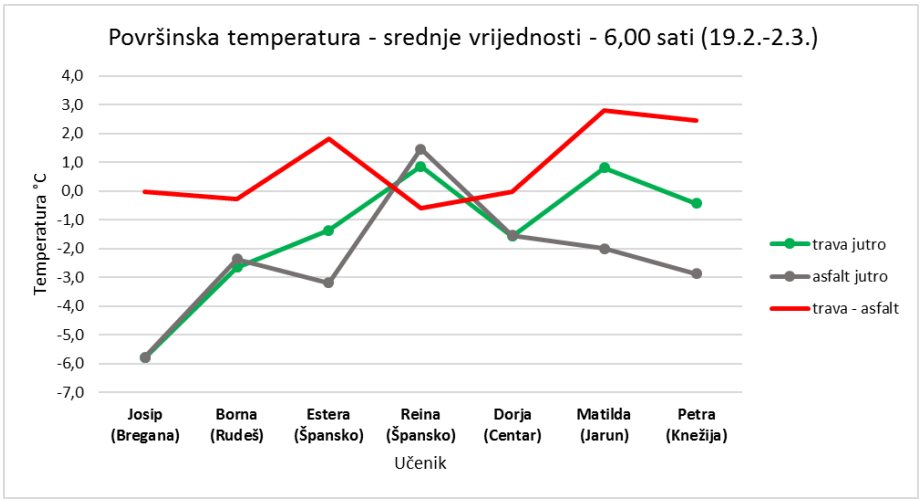
Picture 2. Average Surface Temperature on 3 sites (print screen example)

The mean value of the surface temperature measured on the asphalt and on the grass was graphically presented and the stations at school Vrapče and II Gymnasium were compared.



Graph 1. Comparison of average surface temperature values of grass and asphalt on school sites (Vrapče and II Gymnasium)

Graph 1 shows that during the study period the mean surface temperatures of asphalt and grass at Vrapče station were lower than those measured at stations II. Gymnasium. The total mean surface temperature values measured at 6.00 h at the asphalt and grass stations are presented graphically. We also calculated the difference between the measured surface temperature of grass and asphalt.

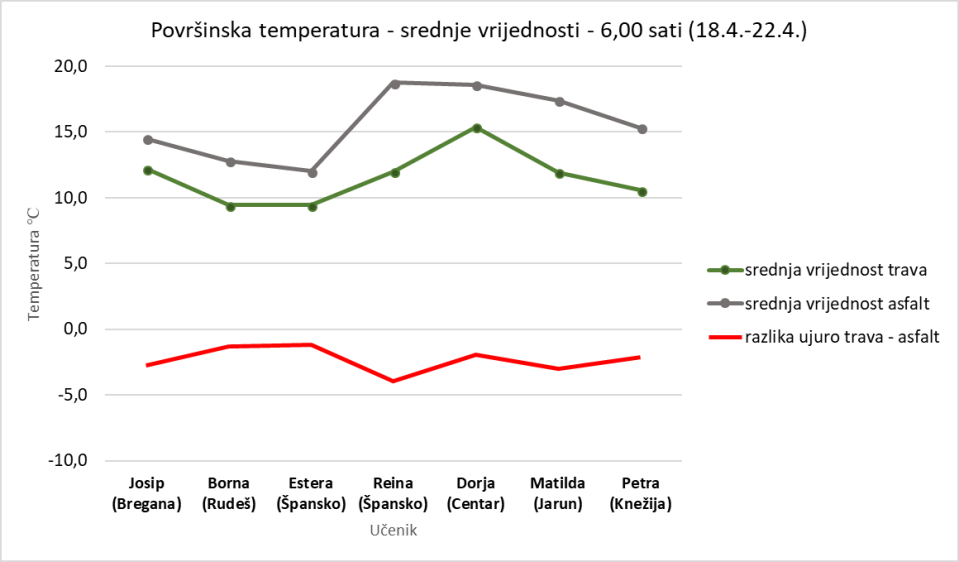


Graph 2. Comparison of average surface temperature values on grass and asphalt at 6.00 am (19.2.-2.3.) and difference between them

Graph 2 shows that in the period 19.2. to 2.3. at 6.00 at most stations there is a difference between the mean surface temperature of grass and asphalt.

In two cases the mean surface temperatures of grass and asphalt were the same (Josip and Dorja), in two cases the mean surface temperature of grass was lower (Borna and Reina) and in three cases the mean

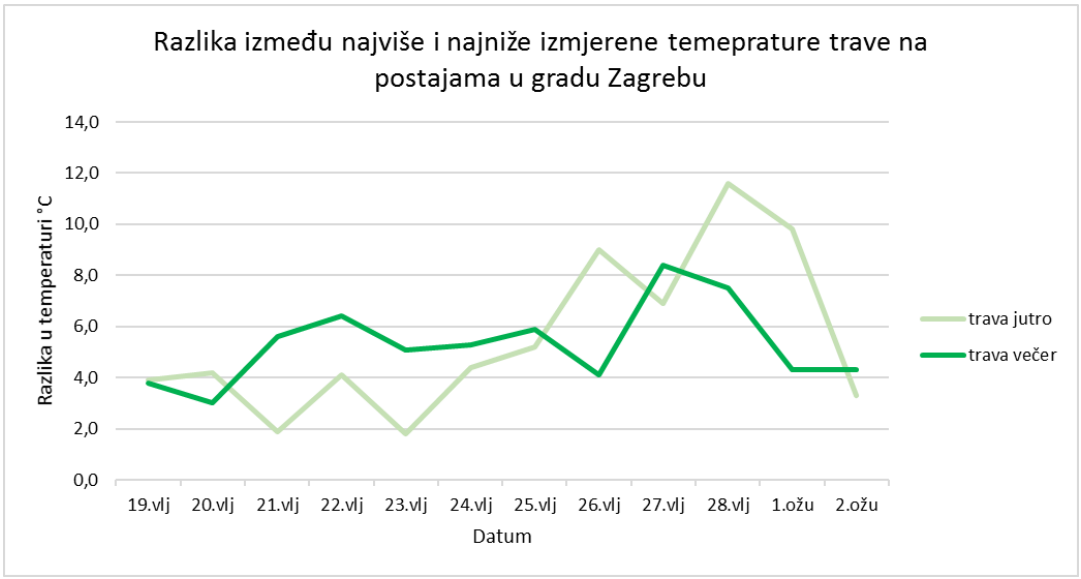
surface temperature of grass was higher than asphalt (Estera, Matilda and Petra). In the graph we can see that the surface temperatures measured by Reina differ significantly from the others.



Graph 3. Comparison of average surface temperature values on grass and asphalt at 6.00 am (18.4.-22.4.) and difference between them

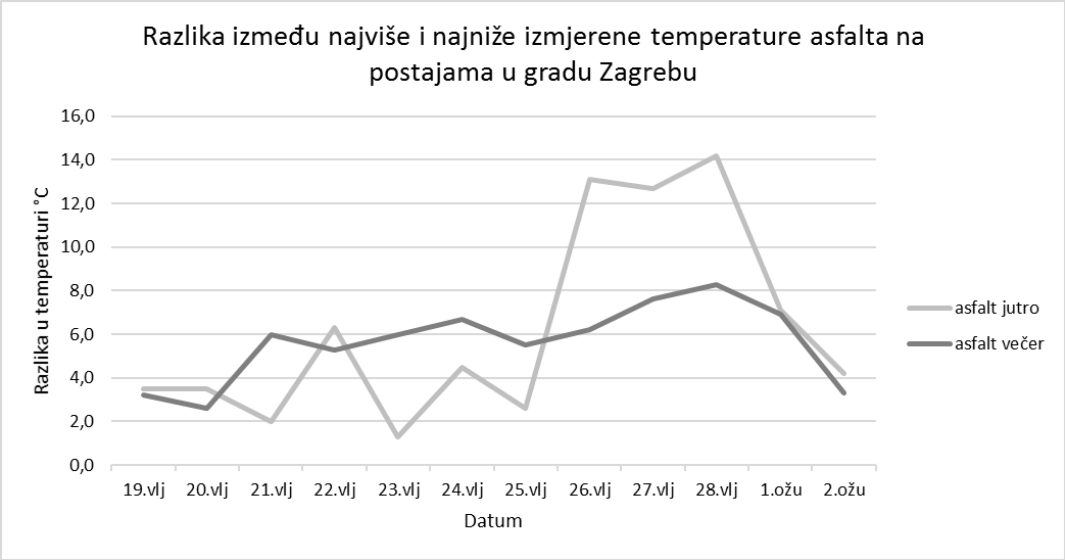
Graph 3 shows that in the period 18.4. to 22.4. at 6.00 hours the mean surface temperature of the asphalt at all stations was higher than the mean surface temperature of the grass.

To show the similarities of temperatures at the measurement stations, we calculated the difference between the highest and lowest measured surface temperatures for each measurement.



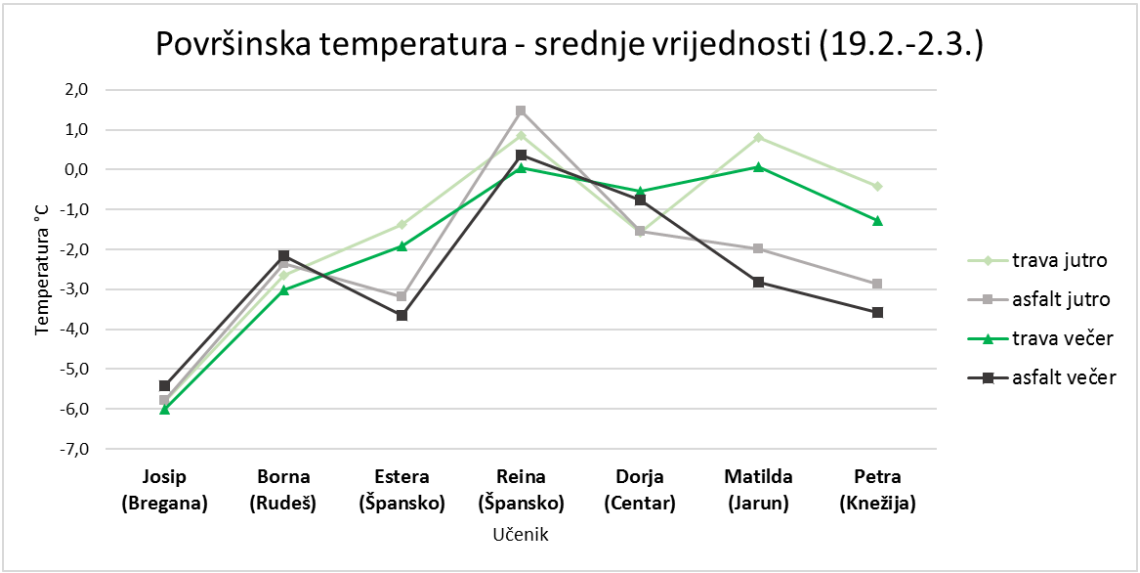
Graph 4. Difference between maximum and minimum surface temperatures on grass sites in Zagreb

Graph 4 shows that during 7 out of 12 days the measurements of the morning surface temperatures at the grass stations were more similar to each other than the evening temperatures.



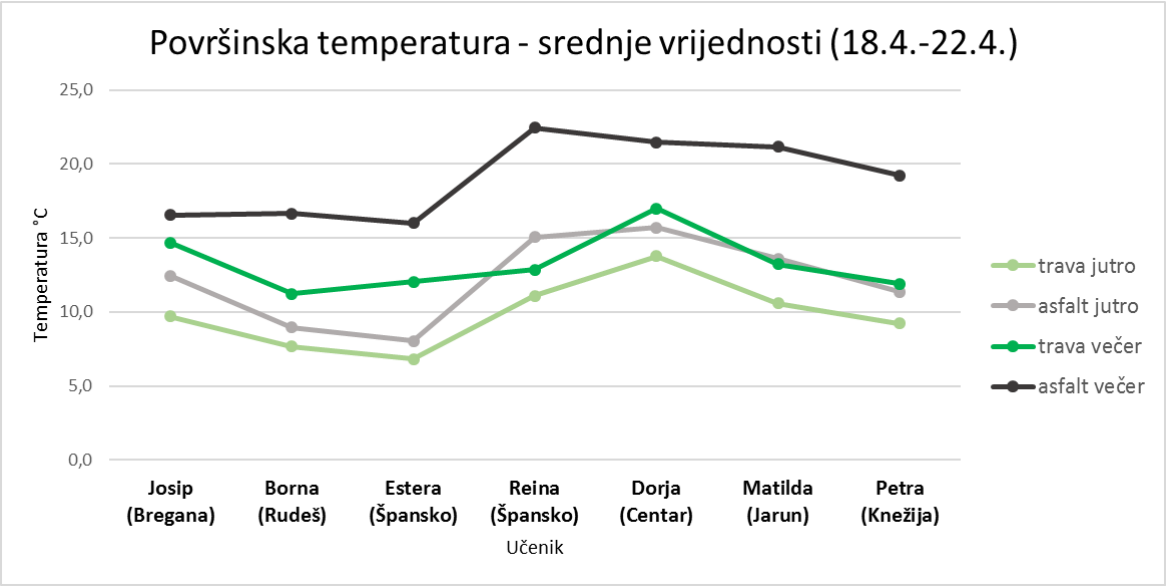
Graph 5. Difference between maximum and minimum temperatures on asphalt stations in Zagreb

From Graph 5 we can read that the morning surface temperatures at the asphalt stations were more similar to the evening ones only for four days .



Graph 6. Average values of surface temperatures of grass and asphalt sites(19.2.-2.3.)

From Graph 6 we can see that the temperatures at Josip in Bregana (rural area) are much lower and with the slightest difference, unlike the temperatures measured by other students. We also see that mean values at Reina in Spansko show higher values than other students'.



Graph 7. Average values of surface temperatures of grass and asphalt sites (18.4.-22.4.)

Graph 7 shows that the morning temperatures at all stations had a lower temperature than the evening ones.

To determine whether the vicinity of the lake has an effect on the surface temperature of the grass surface, we calculated the temperature amplitude of all grass stations during the study period. We have shown the calculation in a tabular visualisation.

Table 1. Temperature amplitude on grass stations for research period between 19.2. and 2.3.

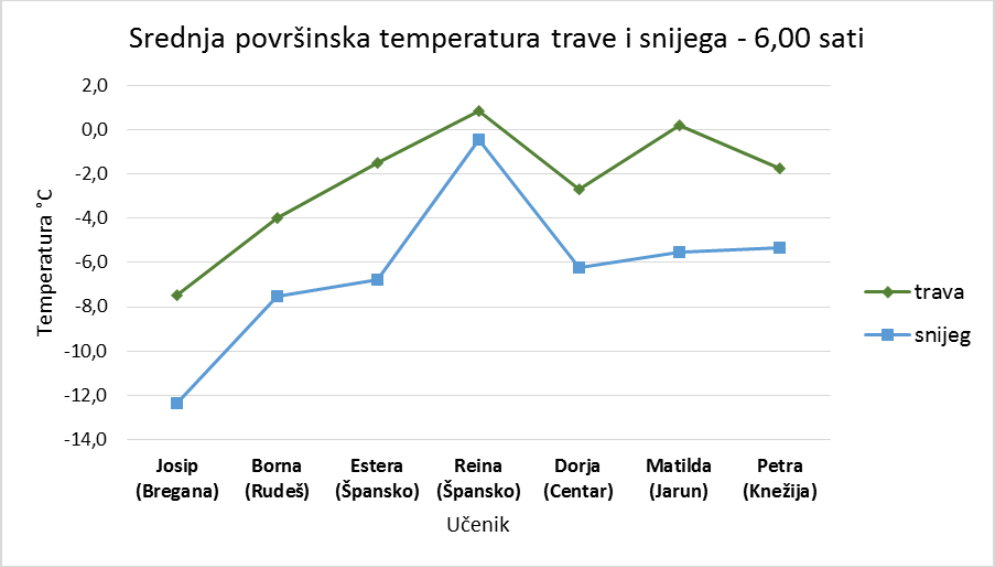
Srednja dnvna temperatura trave	19.vlj	20.vlj	21.vlj	22.vlj	23.vlj	24.vlj	25.vlj	26.vlj	27.vlj	28.vlj	1.ožu	2.ožu	amplituda (max. - min.)
Josip (Bregana)	-2,9	-1,7	-2,2	-3,6	-3,8	-4,8	-8,6	-7,4	-8,7	-12,0	-8,3	-7,0	10,3
Borna (Rudeš)	-0,8	0,0	-0,6	-1,4	1,4	1,3	-5,3	-5,9	-6,5	-7,7	-6,0	-2,6	9,0
Estera (Špansko)	-1,0	-1,2	-1,6	0,5	0,8	-1,0	-3,0	-4,5	-3,9	-2,8	-2,0	-0,1	5,3
Reina (Špansko)	1,0	2,4	2,1	-0,8	3,1	1,9	-3,6	0,0	1,2	0,9	-3,0	0,2	6,6
Dorja (Centar)	1,0	0,6	0,3	1,0	1,4	-2,5	0,3	-3,8	-2,7	-3,0	-4,3	-1,0	5,7
Matilda (Jarun)	1,7	2,1	0,9	1,7	1,6	0,7	-0,7	-1,7	-0,3	-2,5	1,0	0,8	4,6
Petra (Knežija)	1,3	1,7	0,8	1,1	1,3	0,5	-1,9	-3,5	-3,7	-4,2	-3,9	0,8	5,9

Table 2. Temperature amplitude on grass stations for research period between 18.4. and 22.4.

Srednja dnvna temperatura trave	18.tra	19.tra	20.tra	21.tra	22.tra	amplituda (max. - min.)
Josip (Bregana)	12,1	10,2	11,4	11,9	15,5	5,3
Borna (Rudeš)	9,8	7,3	10,4	9,5	10,4	3,1
Estera (Špansko)	9,3	7,9	11,3	9,4	9,5	3,5
Reina (Špansko)	11,6	10,1	12,2	11,8	14,2	4,2
Dorja (Centar)	14,3	14,1	15,3	17,3	16,0	3,2
Matilda (Jarun)	11,2	11,9	13,6	11,0	11,9	2,6
Petra (Knežija)	10,1	10,5	12,6	9,2	10,6	3,5

From Tables 1 and 2, we can see that the smallest amplitude of the surface temperature of grass has stations near Lake Jarun.

From 23.2 to 2.3. there was snow on all the grassy surfaces, so the surface temperatures of snow and grass were shown graphically.



Graph 8. Average surface temperature of grass and snow for period between 23.2. and 2.3.

From Graph 8 we can see that at all stations the grass surface temperature was higher than the snow temperature.

Discussion and conclusions

Comparing the data from the measuring stations of our schools, we found that grass and asphalt substrate temperatures were lower at the Vrapče station. With that we confirmed our hypothesis that downtown temperatures are higher than those in the suburbs.

It is also evident from all the graphs shown that the rural area has a lower temperature than all the city stations. With this we also confirmed the existence of a heat island made by the city of Zagreb.

Our hypothesis that the asphalt will have a lower temperature than the grass we did not confirm.

Comparing the measurements, we obtained that the surface temperature of the asphalt was lower at only three stations, at two it was the same and at two it was higher than the grass surface, and we consider that this is not a statistically valid ratio to confirm the given hypothesis.

From the graphical visualisation we can see how the values of the measured surface temperatures differ depending on the proximity of the city or the water body. The station in the center has higher measured surface temperatures (especially asphalt substrate) than the temperatures measured at 'outside' stations (Rudeš, Špansko, Knežija) which was our assumption. Although Reina's station in Spansko is located outside the center of Zagreb, her measured temperatures are the highest and deviate from all other stations. We believe there is a possibility that there is a city hot water pipe near her station.

We tried to confirm the similarity of temperatures between stations with a smaller difference between the measured temperatures. In this account we omitted the station from Bregana because it is completely outside Zagreb. Our assumption that morning values between stations will be more similar due to cooling during the night has not been confirmed for both substrates.

It was confirmed for grassland because the morning temperatures were seven days more similar to one another in the morning than in the evening, but the asphalt proved to be the opposite, with the evening temperatures eight times more similar to those in the morning. During the second research period, the surface temperature of the asphalt at all stations was higher than the grass surface.

The hypothesis of the influence of the lake as a climatic factor on surface temperature oscillations has also been confirmed.

Due to the expected higher water content in the soil at the station near Jarun, we expected the grass surface temperature to be more uniform. Water regulated the rate of change of temperature, so the value itself changed more slowly and less than the values measured at other stations.

We have confirmed our hypothesis that snow will serve as an insulator and that it will have a lower temperature than the substrate on all grass stations. We did not test the same hypothesis on asphalt pavement because we did not have continuity of coverage at all stations, that is, snow was already cleared before measurement.

Literature

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2. Surface Temperature Protocol
3. Surface Temperature Data Sheet
4. Surface Temperature eTraining

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8. http://blog.meteo-info.hr/meteorologija/zagreb-toplinski-otok/ (12.2.2018.)

9. http://www.enciklopedija.hr/natuknica.aspx?ID=61793 (16.3.2018.)

Badges:

Be a Collaborator

All team members are listed, from both school. Their roles are defined and descriptions cleary indicate the contribution of each student. Their collaboration improved the research because in each school they have different type of school subjects (different levels and areas of STEM subjects) so they learned from each other and compared their knowledge in basic level at the start and then at the end of the project. They also improved they IT skills, they were online every day during measuring, exploring data etc.

Be a STEM Professional

While conducting their research students were constantly in contact with Dubravka Rasol, scientist in National Meteorological and Hydrological Service. She helped and supported their collecting and analyzing data and pointed out how to interpret and present the data. As a result project was presented at Annual GLOBE Meeting in Croatia

Be a STEM Storyteller

Students wanted to show how the heating in general damage the Earth. In that purpose they made a video as an artistic way of presentation of that problem. Video was also included in EU contest for schools who are engaged in environmental issues. Video also includes the vocational occupation of our students – future nurses. (https://www.youtube.com/watch?v=QRd6v_zIc28)